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NUMERICAL INVESTIGATION ON SHELL & TUBE HEAT EXCHANGER WITH SEGMENTAL AND HELIX BAFFLES

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ABSTRACT

Shell and Tube heat exchangers are widely used in many industries as they are very efficient in exchanging heat between two or more fluids when compared to other types of Heat Exchangers. Various heat transfer augmentation techniques (passive, active or combination of both) are already present to enhance the heat transfer capability and were used mainly in many areas of process industries, refrigerators, thermal power plants, automobiles, etc. In this paper, a brief numerical comparison of shell & Tube heat exchangers is presented in detail representing the best possible augmented heat transfer along with heat transfer characteristics. For this, a shell & Tube heat exchanger with Helix baffle plate varying the pitch of helix, shell & tube heat exchanger with segmental baffle plate varying baffle spacing along with tubes with fins are targeted to enhance the maximum possible heat transfer. Finite volume numerical simulation is performed on the above three Heat exchangers using ANSYS Fluent version 17.2. Convergence criteria residuals of the order 10^{-6} are adopted for convergence acceleration. Mesh refinement is done until convergence is reached. Heat transfer coefficient, pressure (p) and Nusselt number (Nu_s) is visualized along the length of the heat exchanger. The heat exchanger which exhibits better performance characteristics compared to the other two types of Shell & Tube Heat Exchangers is to be selected for further applications to maximize the overall efficiency of the system.

***KEYWORDS**: Heat Exchangers, Heat Transfer Augmentation Technique, Helix Baffle Plates & Segmental Baffle Plates*

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Original Article

INTRODUCTION

A heat exchanger device could be a piece of machinery designed for the transfer of heat between two mediums, it is therefore, necessary that it has huge contact surface areas of material separating every medium. The key limitation is that they cannot be accustomed to regenerate, however, they can transfer a huge amount of heat due to the huge surface area. Some of the commercial uses for heat exchangers include home radiators and hot water radiators. The Fluid Flow behavior along with heat transfer for heat exchangers with continuous STHxHB and STHxSB is studied in this paper by various experiments. By experimental results, continuous STHx-HB Heat exchangers will increase heat transfer rate by 7-12% than STHx-HB Heat exchanger for a few “m” and its heat transfer area is reduced by 3%. The heat transfer coefficient and “P_d” of continuous STHx-HB Heat exchangers had

43.53% and 64.72% will increase those that of STHx-HB Heat exchangers. Supported second law physical science comparison during which quality of energy is evaluated by the entropy generation variety. The continuous STHx-HB Heat exchangers reduced the entropy generation number by 30% on average than the STHx-HB Heat exchangers for same Reynolds number. Correlations for "Nu_s" and friction factor kept constant for, CH/SG = 0.28. [1]

Bell-Delaware methodology for STHx with SB has been developed. A range of curve sort factors is replaced by mathematical expressions. Here four design cases of replacement of original STHx with SB. The comparison results of STHx with HB which have higher performance than original heat exchangers. With the choice of geometric parameters, the replacement of Heat exchangers with STHx-HB with Heat exchangers with STHx-SB sometimes scale back the "Pd" of the shell side and cut back the heat transfer area. The accuracy of present methodology will meet the need of engineering knowledge. [2]

Now for high "P_d" in standard segmental baffles in heat exchangers, the sextant fan bottle was argued. It supported baffle curvature radius of Sextant fan in shell and tube heat device SFTHX on shell aspect "P_d", heat transfer coefficient, performance, attack completely different curvature radius is numerically simulated. The SFTHX with baffle radius of curvature one dimensional which is exaggerated from 0.84%-6.85% more than others. Heat transfer coefficient in SFTHX-D is 0.74%-6.85% beyond different performance of SFTHX-D is 0.84%-6.85% bigger than others which ends up higher heat transfer performance. [3]

The hydraulic analysis of the heat exchanger may be a necessary equipment to assure success of any of the ways offered here. During this paper the author urged that the connection between the threshold constant and the logarithmic decrement of damping be used for the fluid elastic furthermore because of the vortex shedding mechanisms. The connections ought to be supported the flow and structural configurations of the particular device. He additionally said that to the various anti-vibration methods described it is necessary to consider related aspects of the problem, such as prediction of amplitude, forces, tube stresses, fatigue and fretting. [4]

There are two sorts of bakers. One among the bakers is baker yeast that is 5% dry in weight and so the second is dodecane-water emulsion which is 0.1%. The result of variety of helices reference to baffle length shows that the permeate volume will increases number of helices, however to a lesser degree once the number of helices is more than 4 per 25mm length of the baffle. A small variation in permeate flux values are observed when the baffle's maximum diameter was reduced by about 40%. The STHx-HB baffled cross flow microfiltrations were found to be easy and effective. The manufacture of this baffle in metal or plastic is straight forwarded. [5]

MODELLING, MESHING AND ANALYSIS OF HEAT EXCHANGER

Here the shell and tube device with baffles are placed on shell in alternate orientations so as to form flow methods across the bundle. The modelling is compared by varying the baffle spacing, i. e. 82 mm, 86 mm, 90 mm additionally fins are also placed to ascertain wherever the warmth heat transfer rate is a lot [6]. The CFD analysis involves pre-processing, explanation and post-processing. The modelling is completed by Solid works software as it is easy to model a Heat exchanger in 3D modelling code and then it is imported to Ansys 17.2

Table 1: Dimensions of Heat Exchanger

Length of the heat exchanger, *L*	600mm
Inner diameter of the shell, *Di*	90mm
Outer diameter of the tube, d_o	20mm
Geometry and pitch Triangular of tube bundle	30mm
No.of tubes, *Nt*	7
No. of baffles, *Nb*	6
Spacing of baffle at center, *B*	82mm, 86mm, 90mm

Geometry Modelling

In SOLID WORKS the model is created. Later the model is saved in Para solid type file i.e. (xt). The external geometry file is imported into the design modeller of the Ansys Fluent. Here the placement of fins is also done.

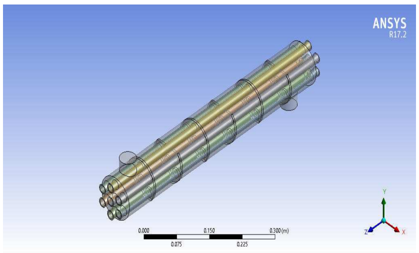

Figure 1: Geometry of STHx-SB (Without fins)

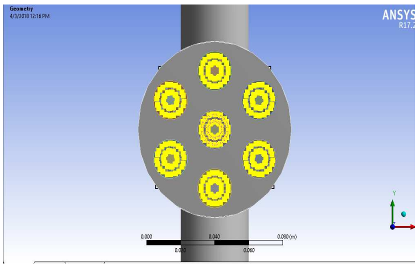

Figure 2: Geometry of STHx-SB (with fins)

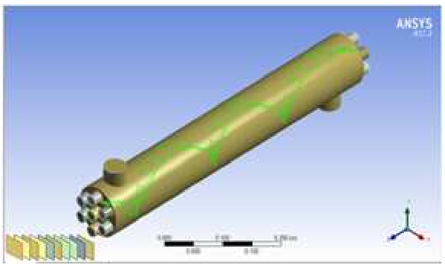

Figure 3: Geometry of STHx-HB (without fins)

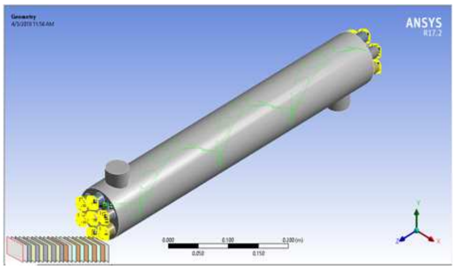

Figure 4: Geometry of STHx-HB (with fins)

Meshing

In free meshing, a relatively coarse mesh is generated. At the boundaries of every tetrahedral and hexahedral cell, triangular faces are seen. Once a fine mesh is generated victimization edge size is seen. Here the edges and regions of gradient and high pressures area unit finely meshed.

Number of Elements and Nodes

The element is the basic building block of finite element analysis. These elements are often lines, areas or solids. It additionally relates however, the deflections produce stresses. A node could be a coordinate location in the house wherever the degrees of freedom are outlined. The degrees of freedom for now, represent the attainable movement of now because of the loading of the structure [7]. The degrees of freedom additionally represent that forces and moments are transferred from one part to subsequent. The results of a finite part analysis are typically given at nodes. The table for nodes and components are drawn below for STHx-SB and STHx-HB meshing.

Table 2: Segmental Baffle – Without Fins

Baffle Spacing	Nodes	Elements
82 mm	328706	671598
86 mm	324667	662399
90 mm	320747	646996

Table 3: Segmental Baffle – With Fins

Baffle Spacing	Nodes	Elements
82 mm	388258	641664
86 mm	388899	645237
90 mm	388936	645568

Table 4: Helix Baffle– Without Fins

Baffle Spacing	Nodes	Elements
82 mm	328169	688656
86 mm	328305	689332
90 mm	328281	688816

Table 5: Helix Baffle– With Fins

Baffle Spacing	Nodes	Elements
82 mm	398358	687228
86 mm	396494	687904
90 mm	364576	687491

Figure 5: Meshing of STHx-SB. (without fins)

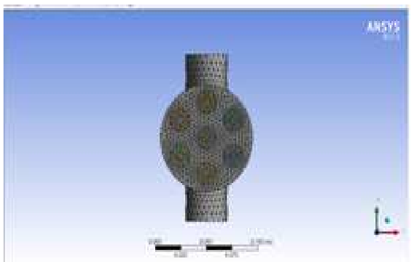

Figure 6: Meshing of STHx-SB (with fins)

Figure 7: Meshing of STHx-HB (without fins)

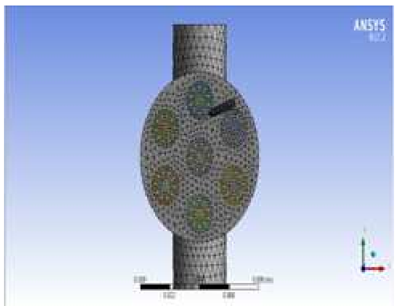

Figure 8: Meshing of STHx-HB (with fins)

BOUNDARY CONDITIONS

At different zones of Heat exchanger, different boundary conditions were applied. The tube side inlet temperature is 298K and shell side inlet temperature is 373K. The inlet velocity of the shell side varies depending on the "m" i.e. 1.5915m/s, 3.1831m/s, 4.7746m/s, 6.36619m/s respectively. Whereas the inlet velocity of the tube side remains constant, i. e. 0.4547 m/s.

Fluid Properties

The fluid considered in shell side and the tube side is water. The properties of water are listed below:

- **Density of water:** 992.2 kg/m^3
- **C_p of water:** 4182 J/kg-K
- **Water thermal conductivity:** 0.6 W/m-K
- **Viscosity of water:** 0.001003 Kg/m-s

Notations

In this paper, some notations are present. Those are listed below

- **STHx:** Shell and Tube Heat Exchanger.
- **STHx-SB:** Shell and Tube Heat Exchanger with Segmental Baffle Plates.
- **STHx-HB:** Shell and Tube Heat Exchanger with Helical Baffle Plates.
- **Mass flow rate:** m
- **Pressure drop:** P_d
- **Nusselt number:** Nu_s
- **Heat transfer coefficient:** h
- **Pressure:** p

RESULTS

The analysis was in deep trouble for the Heat exchangers having STHx-SB and STHx-HB and therefore graphs were planned. The graphs were drawn by varying "m" with respect to heat transfer coefficient, pressure, Nusselt number and heat transfer coefficient per pressure drop. All together cases compared to Heat exchangers without fins, with fins are more efficient.

STHx-HB Baffle Graphs

The heat transfer coefficient with "m" of water is planned in Figure 9 for each with fins and without fins in a heat exchanger. It may be ascertained that the position of fins in the device provides additional heat transfer rate compared to without fins. The heat transfer coefficient there on fluid aspect is comparatively low once the area is enhanced by the fins and consequently increases the total rate of heat transfer.

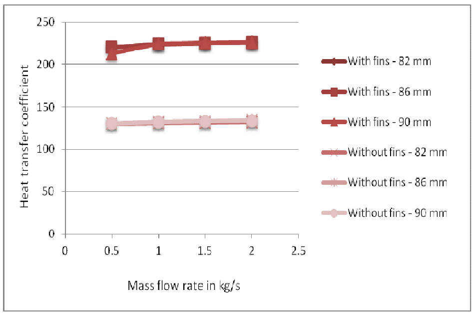

Figure 9: "m" Vs "h"

The variation of "p" with the flow rate of water is shown in Figure 10. The flow of water modified from 0.5kg/s to 2kg/s for the projected shell and tube device with fins and without fins. It measures typically seen that "p" for every kind changes slightly. Step by step there will be an increase of "p" with a flow rate of water is higher simply just in case of with fins than that of without fins is also seen from the slope of the curves in Figure 10.

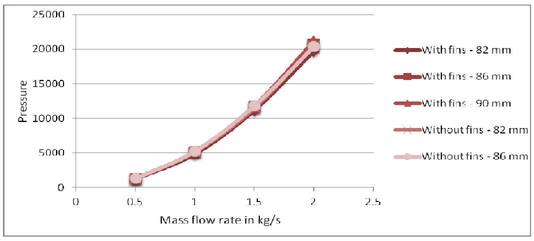

Figure 10: "m" Vs "p"

For the validation of the STHx-HB baffle plates with fins, "Nu_s" with "m" of water is calculated for Shell and Tube device STHx-HB. Those calculated values are then compared with the baffle plates without fins that show sensible agreement. The slight deviations are seen because of the change of "m" with the "Nu" and "Nu_s" are going to be high once the fin is placed within the device compared to without fins.

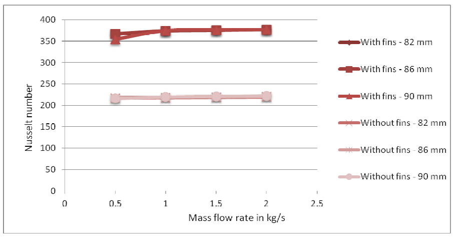

Figure 11: "m" Vs "Nu_s"

In the case of heat transfer coefficient per "Pd" will operate the "m" of water it is clearly ascertained once the fins are placed within the device, the "m" decreases step by step. However the case of without fins baffle spacing 86mm, the "m" will increase to the bound amount and reduces. For the remaining cases with fins and without fins within the device, we will see the decreasing of the "m". This is often clearly seen in Figure 12.

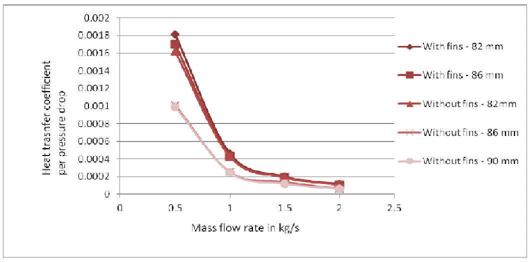

Figure 12: "m" Vs "h/P_d"

STHx-HB Baffle Graphs

In the case of heat transfer coefficient and "m", we will see plenty of increase in heat transfer when we put next to without fins given in the device. However, after we compare the baffle spacing i.e. 82mm, 86mm and 90mm with fins only slight changes in heat transfer is seen. The heat transfer coefficient will increase slowly with the increased. It will be ascertained that heat transfer coefficient just in case of with fins is on top of that of without fins which are seen in Figure13.

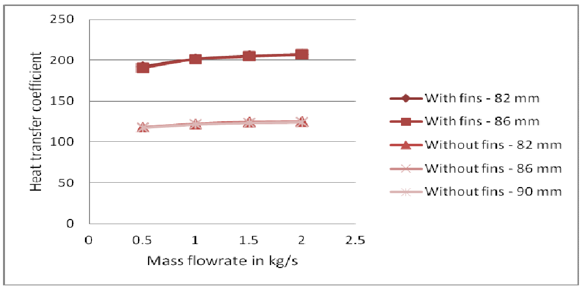

Figure 13: "m" Vs "h"

The variation of "p" with the flow rate of water is shown in Figure13. The rate of water changed from 0.5kg/s to 2kg/s for the projected shell and tube device with fins and without fins. It is usually seen that "p" for each kind changes slightly. Bit by bit there will be an increase of "p" with a flow rate of water is higher simply just in case of with fins than that of without fins could also be seen from the slope of the curves in Figure 14.

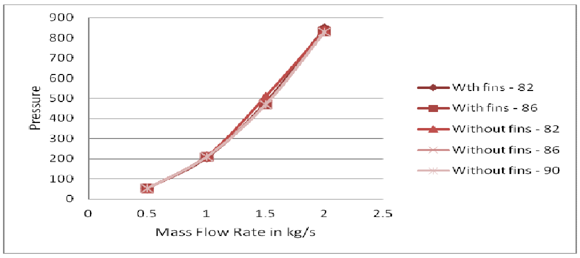

Figure 14: "m" Vs "p"

For the validation of the STHx-HB baffle plates with fins, the "Nu_s" with the mass rate of water is calculated for Shell and Tube device and therefore graph is premediated between with fins and without fins. The obtained graph is similar to heat transfer coefficient per "m".

The slight deviations are also seen because of the modification of "m" with the Nu number and "Nu_s" are high once the fin is placed within the device compared to without that is seen in Figure 15.

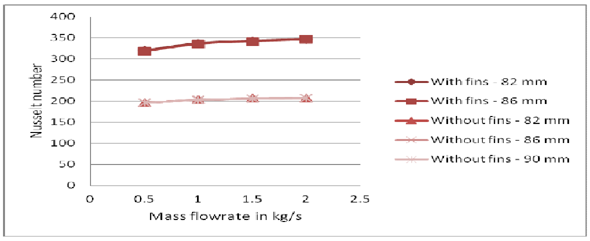

Figure 15: "m" Vs "Nu"

In the case of "h/P_d" with the function of "m" of water, it is clearly ascertained that the "m" decreases step by step. The comparison is taken among the heat exchangers without fins, however, in this case with fins, there is no deviation among 82mm, 86mm, and 90mm. The "m" will increase to the sure amount and reduces. This is due to the "P_d" in the fluid considered. For the remaining cases with fins and without fins in the heat exchanger, we can see the decreasing of the "m", this is observed due to the thermal load and allowed "P_d". This is clearly seen in Figure 16.

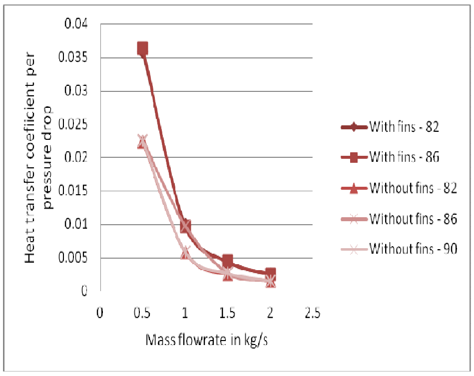

Figure 16: "m" Vs "h/P_d"

CONCLUSIONS

In this paper, Numerical comparison of STHx with both segmental and helical baffles is done. The helix baffle plate is enhanced by varying the pitch of helix and segmental baffle plate is enhanced by varying the baffle spacing. By using ANSYS fluent 17.2 the convergence criteria, finite volume numerical simulations are performed for above two Heat exchangers. For the present geometry, heat transfer coefficient, pressure, Nusselt number and heat transfer coefficient per pressure drop are visualized as a function of "m" of water.

As a result,

- The presented graph shows for both with fins and without fins. Mainly it can be seen that heat transfer coefficient is higher than with fins than that of without fins.
- The presented geometry also shows the increase the rate of "p" with "m" in case of with fins than that of without fins.
- Here, it is observed that the "Nu" is higher in case of with fins than that of without fins.
- At last the comparison for "h/P_d" with respect to mass flow rate, it seems that with fins having higher "h/Pd" than without fins.

The presented geometry exhibits better performance compared to other heat exchangers.

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